

PROPOSAL

The Development of Design and Construction Guidance for Special Facilities for Vertical Evacuation From Tsunami

A. Background

The National Tsunami Hazard Mitigation Program (NTHMP), which is lead by the National Oceanic and Atmospheric Administration (NOAA), was established and funded by Congress to reduce the risk posed by the tsunami hazard. Since tsunami is an earthquake-generated hazard, it is also referenced in the National Earthquake Hazard Reduction Program (NEHRP). The NEHRP, which is currently led by the Department of Homeland Security's Federal Emergency Management Agency (FEMA), was also established and funded by Congress to reduce the risk posed by earthquakes. Both agencies have sought to establish a coordinating role between the two programs. Additional information on the NTHMP can be found on their website, (www.pmel.noaa.gov/tsunami-hazard/).

One of the programmatic questions that have become central to the NTHMP is whether it is possible to build a structure that would be capable of resisting the extreme forces of a tsunami. This question is being driven by the fact that there are several coastal communities along our nation's west coast that are vulnerable to tsunami triggered by an earthquake on the Cascadia Subduction Zone which could potentially generate a tsunami within minutes. Given that many of these coastal communities are located in areas that would be impossible to evacuate in time and so could result in a significant loss of life, we are looking for alternatives. The only feasible alternative would be vertical evacuation, if such a structure could be constructed to resist tsunami loads.

FEMA Coastal Construction Manual

FEMA's most recent study of coastal seismic and tsunami loads was done in association with the FEMA Coastal Construction Manual (FEMA-55). This manual was developed to provide design and construction guidance for structures built in coastal areas throughout the United States. The Coastal Construction Manual (CCM) does address seismic loads for coastal structures, and does present a seismic response factor for pile-supported construction. The CCM also does provide information on the tsunami hazard. Section 7.2.2 of the CCM states that:

"Tsunamis are long-period water waves generated by undersea shallow-focus earthquakes or by undersea crustal displacements (subduction of tectonic plates), landslides, or volcanic activity. Tsunamis can travel great distances, undetected in deep water, but shoaling rapidly in coastal waters and producing a series of large waves capable of destroying harbor facilities, shore protection structures, and upland buildings (see Figure 7-6). Tsunamis have been known to damage some structures hundreds of feet inland and over 50 feet above sea level. Coastal construction in tsunami hazard zones must consider the effects of tsunami runup, flooding, erosion, and debris loads. Designers should also be aware that the

“rundown ” or return of water to the sea could also damage the landward sides of structures that withstood the initial runup.

“Tsunami effects at a particular site will be determined by four basic factors:

- the magnitude of the earthquake or triggering event
- the location of the triggering event
- the configuration of the continental shelf and shoreline
- the upland topography

“The *magnitude* of the triggering event determines the period of the resulting waves, and generally (but not always) the tsunami magnitude and damage potential. Unlike typical wind-generated water waves with periods between 5 and 20 sec, tsunamis can have wave periods ranging from a few minutes to over 1 hour (Camfield 1980). As wave periods increase, the potential for coastal inundation and damage also increases. Wave period is also important because of the potential for resonance and wave amplification within bays, harbors, estuaries, and other semi-enclosed bodies of coastal water.

“The *location* of the triggering event has two important consequences. First, the distance between the point of tsunami generation and the shoreline determines the maximum available warning time. Tsunamis generated at a *remote source* will take longer to reach a given shoreline than *locally generated* tsunamis. Second, the point of generation will determine the direction from which a tsunami approaches a given site. Direction of approach can affect tsunami characteristics at the shoreline, because of the sheltering or amplification effects of other landmasses and offshore bathymetry.

“The *configuration* of the continental shelf and shoreline affect tsunami impacts at the shoreline through wave reflection, refraction, and shoaling. Variations in offshore bathymetry and shoreline irregularities can focus or disperse tsunami wave energy along certain shoreline reaches, increasing or decreasing tsunami impacts.

“*Upland elevations and topography* will also determine tsunami impacts at a site. Low-lying tsunami-prone coastal sites will be more susceptible to inundation, tsunami runup, and damage than sites at higher elevations. Table 7.4 lists areas that are subject to tsunami events, and the sources of those events. Figure 7-7 shows tsunami elevations with a 90-percent probability of being exceeded in 50 years.”

With regard to designing to resist tsunami loads, Section 11.7 of the CCM states that:

“Tsunami loads on residential buildings may be calculated in the same fashion as other flood loads; the physical processes are the same, but the scale of the flood loads is substantially different in that the wavelengths and runup elevations of tsunamis are much greater than those of waves caused by tropical or extra tropical cyclones. If the tsunami acts as a rapidly rising tide, most damage will be caused

by buoyant and hydrostatic forces (see *Tsunami Engineering* [Camfield 1980]). When the tsunami forms a borelike wave, the effect is a surge of water to the shore. When this occurs, the expected flood velocities are substantially higher. Both Camfield and Dames & Moore (1980) suggest that this velocity should be $V = 2(gd)^{0.5}$. Figure 11-16 shows the relationship between design stillwater depth and expected velocity for tsunami and non-tsunami conditions. The tsunami velocities ... are very large and if realized at the greater water depths, would cause substantial damage to all buildings in the path of the tsunami. Designers should collect as much data as possible about expected tsunami depths to more accurately calculate tsunami flood forces.”

The conclusion of the CCM’s authors is that tsunami loads are far too great and that it is generally not feasible or practical to design normal structures to withstand these loads. It should be noted that study was for conventional construction, and did not take into account the possibility of special design and construction details that would be possible for critical facilities.

First Phase

Work on this issue has already been initiated under a project managed by the State of Washington under a \$100,000 grant that was funded by NOAA under the NTHMP. This Phase 1 activity consisted of collecting potential data regarding tsunamis and the their forces through two subcontracts. This work was preceded by a workshop on this issue with engineers from the different States that was held last year. This was funded under a \$35,000 grant. A report on this work has been issued by the NTHMP.

B. Proposal

FEMA is proposing a project that would be equally co-funded between FEMA and NOAA to determine whether it would be possible to design and build a structure withstand specific tsunami loads, and, if so, to fund the development of a technical design and construction guidance document for special facilities that would allow for vertical evacuation from tsunami conditions. This work would continue and build on the work started in Phase 1.

Given the significant level of risk that exists for the residents of the applicable coastal communities in the Pacific Northwest, Alaska, and Hawaii, it is our belief that co-funding with NOAA the development of a document that will provide design guidance for the design of structures that could be used for vertical evacuation will be a significant step towards improving the protection of the residents of these communities.

C. Project Tasks

Task 1: Development of Project Work Plan

Utilizing the contract Statement of Work and with input from FEMA and NOAA, the Contractor shall develop a Project Work Plan that specifies how the Contractor plans to address the tasks specified in this proposal. The Work Plan will be submitted within one month and then reviewed by FEMA and NOAA. If necessary, the Work Plan will be revised and resubmitted.

Task 2: Project Management

The Contractor will appoint a single Project Director who shall have overall responsibility for management of the Project. The Contractor will also appoint a small Project Management Committee (PMC) comprised of the Project Director as chair and a small group of four eminently qualified academic and practicing experts. The PMC will include at least one representative from the State agencies currently involved in the NOAA NTHMP, a researcher with applicable experience in the effects of tsunami forces and loading, and one practicing engineer with applicable design experience. The PMC will be responsible for the technical quality and practical direction of the project. The PMC will review project activities on a regular basis and be available for immediate consultation as required. All project documents will be approved by the PMC prior to distribution.

A Project Review Panel (PRP) of approximately six to eight members will be appointed to conduct an independent review of the project upon completion of the project work plan, completion of all draft documentation, of the draft and final workshop materials, and the final project report. PRP members will have the same qualifications as the PWG, but will also include representation from appropriate State and local agencies, academic researchers, practicing design engineering firms, construction materials industry experts, and knowledgeable state or local building code professionals.

Selection of all of the above personnel will take into consideration balance between experience in different areas of expertise as well as geographic and professional background. All selections will be made in consultation with FEMA and NOAA. Selection of all personnel shall be completed within one month of the contract.

The Contractor will prepare and submit progress reports on a quarterly basis reflecting the progress made during the reporting period. This progress report will include a brief summary of progress to date, a description of current problems that may impede performance along with proposed corrective action, an estimated completion time for each deliverable item listed, and the financial status to date relative to the original plan, including a breakdown by hours and task for each of the project staff.

Task 3: Review of Relevant Research Documentation and Literature

Building on and taking into account the results of the Phase 1 effort performed by the State of Washington, the Contractor will perform a literature search for relevant information that addresses the design and construction of structures exposed to tsunami and seismic loads. The Contractor will identify and review those publications and

research reports that contain the most recently developed information specific to protection of structures from tsunami and seismic loads. A list of these publications shall be provided to project members as well as FEMA and NOAA for review and approval.

If necessary, and with approval, the Contractor may conduct a limited field investigation to interview knowledgeable sources and obtain additional information. It is estimated that such an investigation would consist of one trip each to the Pacific Northwest and Hawaii.

The results of this task will be described in a Literature Report that will be submitted to the PRP, FEMA and NOAA within 4 months of the contract.

Task 4: The Use of Tsunami Mapping Data:

The NOAA NTHMP is currently mapping tsunami inundation zones, but these maps only show a single zone of inundation and do not provide any characteristics such as the depth and/or velocity of the tsunami. These criteria are developed as part of the mapping process; however, there are several issues that have kept the program from presenting this data on the tsunami inundation maps. However, the depth and velocity of tsunami waters will be critical determining factors as to whether any type of structure would be able to withstand these loads. Therefore, to be useable from an engineering standpoint, the tsunami mapping data such as depth and velocity must be available for design purposes.

The Contractor will review the current NOAA tsunami inundation mapping program to determine how to capture and present tsunami depth and velocity data for design purposes. This data is needed to identify the tsunami force, which would be equal to $\frac{1}{2}$ the depth times the square of the velocity. This force is necessary in order to properly design a facility that would be capable of resisting the anticipated tsunami loads.

A possible solution may be to develop a system that could be used to subdivide or otherwise categorize the current mapping to reflect tsunami depth and velocity. Under this alternative, the data could be used to subdivide the current tsunami inundation maps into a series of zones that would be based on the tsunami force value and would then be used to determine what type of tsunami-resistant structure could be built. One possible proposal would be to use a series of four zones, with the following characteristics:

- the zone where tsunami forces would be so severe that no type of structure (even using this proposed guidance) would survive (the so-called “zone of instant death”) and evacuation to shelter in a lesser zone would be the only alternative;
- the zone where the forces would be slightly less severe and where specially designed structures such as critical facilities for vertical evacuation (such as a special facility could be designed using this proposed guidance) would be able to survive but all other structures would be destroyed;
- the zone where the forces would be low enough that structures such as those designed to the FEMA Coastal Construction Manual would survive although other more normal structures would still suffer significant damage and evacuation might be possible, but only with great difficulty and outside assistance;

- the zone where both the depth and velocity would be low enough that most normal structures would survive with little structural damage (although non-structural/contents damage would still be significant) and residents would be able to evacuate by themselves on foot (the so-called “wet feet zone”).

The development of tsunami-resistant design guidance that is based on use of tsunami depth and velocity data will need to acknowledge and take into account the uncertainty of this data, which is sufficiently unreliable that there has been an historic reluctance to show them on the maps. While this uncertainty is significant, this data does currently represent the best available at this time. Since map data for other hazards, such as for earthquakes, also can have significant degrees of unreliability, this guidance should build on how this lack of reliable data is handled in these other hazards. While this tsunami data may not sufficient reliable to justify widespread public use, it still represents the best data available and should be made available and utilized for specific engineered structures.

The development of tsunami-resistant design guidance using tsunami mapping data should also take into account that such depth data are calculated in relation to mean sea level and do not take into account ground elevation. This guidance will need to address the issue that there may not be sufficiently accurate ground elevation data for the affected areas that can be used in conjunction with the tsunami mapping data. However, since this data would generally only be used for specific engineered structures, the mapping data could be presented as referenced to mean sea level, and then the ground elevation could be determined on a case-by-case basis for the specific structure. Another alternative could be to assume a general estimated ground elevation for the coastal communities involved and present the data based on that estimated value. This would then also provide the data in a form that could be useable by the public, and the designers of the specific structure could then revise the values as needed.

One other issue that would need to at least be discussed by the proposed design guidance is that for the Pacific Northwest, a Cascadia subduction zone earthquake event would also cause subsidence to the land east of the subduction zone. The reason for this is that the overriding North American plate, which is buckling or bulging upward due to the pressure of the subducting Juan deFuca plate, would rebound after an earthquake along the subduction zone. This could result in some level of subsidence in these coastal communities. However, the change in ground elevation cannot presently be reliably estimated, and this represents another issue for further investigation.

The tsunami mapping data investigation will be completed within 9 months of the contract, and the results will be detailed in the State of the Art Report required under Task 6 that will be submitted to FEMA and NOAA within 10 months of the contract.

Task 5: Development of Tsunami Design and Construction Data and Specifications:

In order to determine if it would be possible to design a structure to withstand certain tsunami loads, the Contractor will need to determine potential tsunami loads and how

those loads would affect specific construction materials and design details. This project proposes that any available testing data from the new National Science Foundation (NSF) National Earthquake Engineering Simulation Program (NEES) wave tank facility at the University of Oregon be utilized in this task. Any available research information would significantly improve the proposed Tsunami-Resistant Design Guidance publication, and should be included where possible.

This project does not include funding to conduct actual testing, but the Contractor will contact the NSF, which is a NTHMP and NEHRP partner agency, about funding such a research testing activity using the above facility. The Contractor should explore the possibility of this project being a partner on a NEES Grand Challenge or other funded research activity, since this project will provide an implementation vehicle for those research results, which is a prerequisite for NEES funded projects.

The tsunami design and construction data and specifications investigation will be completed within 9 months of the contract, and the results will be detailed in the State of the Art Report required under Task 6 that will be submitted to FEMA and NOAA within 10 months of the contract.

Task 6: Prepare State of the Art Report

Based on the literature search and the investigations required under Tasks 4 and 5, the Contractor will prepare a State of the Art Report that provides a detailed description of their findings. This report shall include:

- a review of any current documents;
- a description of what information should be included in the proposed manual;
- a description of possible sources for this new information, and;
- an outline of potential designs that would meet the above criteria.

The State of the Art Report will be submitted to FEMA and NOAA for review. Submittal will be within 10 months after signing of the contract. If necessary, review comments will be provided and the State of the Art Report will then be revised to address those comments. A final State of the Art Report will be submitted within 12 months after signing of the contract.

Task 7: Development of Outline for Tsunami-Resistant Design and Construction Guidance Document

Based on the findings and recommendations from Tasks 3, 4, and 5, the Contractor will prepare a topical outline for the new Tsunami-Resistant Design and Construction Guidance Document. The outline shall include a description and source of the information to be provided, and provide an indication of the layout of the manual.

The outline will be submitted to the PRP, FEMA and NOAA for review. Submittal will be within 14 months of the contract. If necessary, all review comments will be addressed.

Task 8: Development of Draft Tsunami-Resistant Design and Construction Guidance Document

Assuming that it would be possible to design a structure to withstand certain tsunami loads, and that FEMA and NOAA agree to exercise the contract option at the 12 month point of the project, the Contractor will develop a design and construction guidance document based on the information obtained from the above issues. This guidance would focus on specially designed structures that would be used for critical functions, including vertical evacuation.

The draft document will be based on, and will incorporate the findings and recommendations of the State of the Art Report, the Tsunami Mapping Report, the Tsunami Design Data and Construction Report, and the review comments from the Outline, the Contractor shall prepare the first draft of the Tsunami-Resistant Design and Construction Guidance Document.

The draft document will be submitted to the PRP, FEMA and NOAA for review within 16 months of the contract. Based on review comments, the Contractor will then revise the draft document and develop the final draft document. A copy of the final draft document shall be submitted to the PO within 19 months after signing of the contract.

Task 9: User Review

During the course of this project, the contractor shall assemble a list of users to review the final draft. The list of reviewers shall include the PRP and the overall list shall be approved by the PRP. The purpose of the review is to ensure that the draft contains material that is technically correct and complete, and to identify any potential problem areas. The list of users shall include State and local officials, researchers, engineers, architects, building code officials, and materials interest groups. This list shall include a minimum of 30 individuals from the above categories, and shall be subject to approval by FEMA and NOAA.

Upon completion of the final draft, the Tsunami-Resistant Design and Construction Guidance Document will be sent out to all members of the users group for review and comment. Reviewers will be given at least one month to accomplish this task. Review comments will either be addressed or explanation provided as to why they were not accepted.

In addition to the above review, the draft document will be placed on a website, the website advertised in appropriate publications, and the website arranged so as to permit the submittal of review comments.

Based on the review comments, the Contractor will modify the final draft Tsunami-Resistant Design and Construction Guidance Document as necessary. This entire task will be completed within 18 months of the contract.

Task 10: Development of the Final Product

Upon successful completion of Task 8 and FEMA and NOAA approval of the final draft Tsunami-Resistant Design and Construction Guidance Document, one camera-ready copy, one electronic copy and 10 paper copies of the Guide will be submitted to FEMA for publication. This will be done within 20 months after signing of the contract. FEMA will handle printing and distribution of the document.

Task 11: Presentation on the Tsunami-Resistant Design and Construction Guidance Document

The Contractor will prepare a presentation on the project and the Tsunami-Resistant Design and Construction Guidance Document. This presentation will be given at a mutually agreed upon conference. One possible location may be the Earthquake Engineering Research Institute's annual meeting. This task will take place after completion of the final draft and within the contract period.

All presentation materials developed for this task will be turned over to FEMA upon completion of this task for future use as training materials.

D. Project Timeline

<u>Project Task</u>	<u>Time Due in Contract</u>
1. Prepare Project Work Plan	1 month
2. Project Management	1 month / continuous
3. Review of Research / State of the Art Report	4 months
4. Use of Tsunami Mapping Data	9 months
5. Develop Design and Construction Data	9 months
6. Prepare State of the Art Report	10 months
7. Prepare Outline of Tsunami Design Guide	14 months
8. Develop draft of Tsunami Design Guide	
a. First draft	16 months
b. Final draft	19 months
9. User Review	18 months
10. Prepare and submit final Tsunami Design Guide to FEMA	20 months
11. Product Presentation	24 months

E. Estimated Project Funding Information

<u>Project Task</u>	<u>Estimated Funding</u>
1. Prepare Project Work Plan	\$ 5,000
2. Project Management	\$ 70,000

3. Review of Research / State of the Art Report	\$ 50,000
4. Use of Tsunami Mapping Data	\$ 50,000
5. Develop Design and Construction Data	\$ 50,000
6. Prepare State of the Art Report	\$ 25,000
Total Base Contract	\$250,000
7. Prepare Outline of Tsunami Design Guide	\$ 50,000
8. Develop draft of Tsunami Design Guide	\$100,000
9. User Review	\$ 50,000
10. Prepare and Submit final Tsunami Design Guide to FEMA	\$ 40,000
11. Product Presentation	\$ 10,000
Total Contract Option	\$250,000
Total Entire Contract	\$500,000

Funding Agencies

Funding for this project will be equally divided between the two funding agencies:

1. Department of Homeland Security, Federal Emergency Management Agency (FEMA)
Using funds from the National Earthquake Hazards Reduction Program (NEHRP)
2. National Oceanic and Atmospheric Administration (NOAA)
Using funds from the National Tsunami Hazard Reduction Program (NTHRP)

Funding will be equally split between FY 2004 and FY 2005. Therefore, with a total project cost of \$500,000, each agency will provide \$125,000 in each of the two fiscal years.